# WTG ENERGY SYSTEMS' MP1-200 - 200 KILOWATT WIND TURBINE GENERATOR

Allen P. Spaulding, Jr.
WTG Energy Systems, Inc.
Buffalo, New York 14203

## INTRODUCTION

The areas to be discussed in this presentation are related to the preliminary design criteria as utilized on the MP1-200. The significance of these design criteria are based on the fact that the MP1-200 is the only wind turbine in operation today that is producing synchronous alternating current using a fixed pitch rotor configuration (fig. 1).

The MP1-200 is installed on Cuttyhunk Island, Massachusetts as part of the Island's independent utility grid system. The municipal utility on Cuttyhunk Island is diesel engine powered with an installed capacity of 465 kW. The annual demand curve, Figure 2, is plotted against the wind turbine's production rate. It is evident from this graph that the wind turbine will have a profound effect on the rate of fuel consumption with the exception of the demand peaks experienced during the summer months. Cuttyhunk Island was chosen as the site for the prototype because it was felt that this type of application was typical of the ideal installation for this type of generating system. As Figure 2 indicates, the wind turbine operates as the dominant power source much of the time. For a wind generator to operate effectively in this type of network it must be capable of maintaining its frequency while operating in parallel with any size conventional power plant.

The MP1-200 became operational as a test unit in June, 1977. Since that time it has been subjected to numeurous operational and environmental tests. The machine has been run for extended periods at 70% over rated speed (80rpm) without damage to any components. It withstood wind velocities in excess of 100 mph on four separate occasions. This machine has proven the concept that a fixed pitch rotor configuration can be utilized effectively at a competitive cost to produce synchronous power under all operating conditions normally associated with conventional generating plants.

## PRELIMINARY DESIGN CONSIDERATIONS

The first step taken in the preliminary design process was to define the potential market for a 200 kilowatt wind generating system. The methods used were simple, direct canvassing of

potential end users; utility companies and large industry, located in areas with high wind regimes. The results of this survey indicated that potential customers would consider a system such as the MP1-200 at an installed cost of approximately $1,000 per kilowatt. In addition the survey indicated that potential buyers wanted a design life for the major components of at least 20 years, synchronous power production directly from the system's generator, minimum service and maintenance, and completely unattended operation over the full operating range of the system.

The second step in the preliminary design process was to conduct an historical survey of large wind turbines. Of particular interest were the fatigue life of large systems and the method(s) used to control rotor speed. Of equal interest was the cost breakdown of these systems. The results of this survey are summarized below.

1. The Gedser Mill as constructed in Denmark in the mid 1950's appeared to be the most fatigue resistent large wind turbine built to date (1974). In addition the costs involved in the construction of this machine were within the guide lines that we had originally set.

2. We found no control systems in the large wind turbines of the past that could meet present day control requirements for synchronous generating systems. All wind turbine control systems up to that time utilized a variable pitch rotor as the primary speed control. The only way that these systems can produce constant voltage and frequency to meet present day standards of accuracy is by parallel operation with a much larger capacity grid system.

3. A third major problem that has plagued large wind turbines is rotor fatigue caused, primarily, by the in plane gravitational loads during operation. A second major contributor to rotor fatigue results from the location of the rotor down wind from the tower causing the blade to 'unload' once per revolution. In addition, this phenomenon has been found to cause erratic behavior in the generator's frequency control system due to momentary loss of torque at the rotor.

## MP1-200 DESIGN CRITERIA

- All steel construction
- 30 year design life for all major hardware components
- Fixed pitch rotor configuration
- Rotor operation up wind of the tower
- Solid state control and speed governing

- Automatic, unattended operation

- Remote monitoring and control capability

- Operational range: 60deg. N to 50deg. S. latitude

- AC synchronous power produced directly from the wind turbine's generator, through out the systems' operating range, in either parallel or independent operation

- +/- 1% control accuracy of frequency and voltage in either parallel or independent generator operation

- $1,000 per installed kW (1975 dollars)

## MP1-200 WIND TURBINE DESCRIPTION

The MP1-200 wind turbine installed on Cuttyhunk Island, Massachusetts, utilizes a three bladed, 80 feet in diameter rotor operating upwind of the tower. The machine is constructed entirely of steel. The tower height, measured from ground level to the rotor's center line, is 80 feet. The rotor operates at a constant 30 rpm driving a 250 KVA synchronous generator through a 40;1 gear transmission. Blade tips rotate 60 degrees out of plane to provide aerodynamic braking. A 24 inch disc brake mounted on the high speed shaft is used for "parking" the rotor. Yaw position is controlled by dual hydraulic servo motors working through two speed reducing transmissions. The entire nacelle assembly rotates on a 59 inch platter bearing. A 72 inch disc brake is provided for locking the yaw position. The tower used is a pinned-truss type, constructed of Cor-Ten steel. Wind speed and direction are sensed on a remote tower and are used to control startup, shutdown and yaw sequences. Components are shown in figure 3.

A system for controlling the speed of the wind turbine has been developed by WTG Energy Systems which utilizes load modulation with the fixed pitch rotor configuration. An industrial process controller is used for the control and monitoring on the MP1-200. This processor represents an ideal compromise in cost, input/output capabilities, processing speed and reliable operation in rough environmental conditions. A versatile software feedback control algorithm is provided and utilized in the speed control system. The controller is an "off-the-shelf" item with no required hardware modifications.

## PERFORMANCE AND OPERATIONAL EXPERIENCE

The MP1-200 has produced power in excess of 300 kilowatts in winds of 35 miles per hour. Operation begins in wind speeds above 8 miles per hour and rated output is achieved at 28 miles per hour. The machine is shut down when the average wind exceeds 40 miles per hour. Power varies directly with

the rotor response to variations in wind velocity about the mean. Power regulation or stabilization of the output is not used in this design. Fluctuations in power approach 30 percent of nominal output in high gusty winds. As a result of the relatively low frequency response characteristics of the high inertia rotor, deviations of this magnitude should not present a problem to most utility networks.

The pitch of the rotor is adjusted initially to reach its peak power coeffecient in winds of 18 miles per hour. In winds above this level the rotor goes into a stalling condition. This condition was found to be gentle and predictable; power continues to increase up to the peak and levels gradually. This phenomenon inherently limits the maximum level of power produced.

Figure 4 shows a strip chart of the wind generator regulating independently of any other source. Regulation of the generator's speed is very good in winds up to 25 miles per hour and tends to degrade slightly above this speed as a result of the high frequency gust components common with higher wind velocities. Worst case accuracy of plus or minus 0.75 hertz (generator output frequency) is specified for isochronous operation. This accuracy is, of course, improved when operating in synchronism with a stable source of equal or greater capacity.

Figure 5 depicts an actual strip chart of the wind generator's performance under synchronous operating conditions. After the speed is adjusted the main contactor is energized. As is standard practice, speed droop is provided on the diesel plant and is adjusted at 2 percent. The load will be divided proportionally to the generator's speed setting. When the wind generator is capable of carrying the entire town load it will do so at a nominal frequency of 60 hertz. The diesel plant will at this point be idling because of its droop setting. As the wind generator's capacity drops ( because of a decrease in wind velocity ) its speed will begin to fall and the diesel set will pick up the proportion of load dropped by the wind generator thus allowing the generators to maintain nominal frequency while dividing the load proportional to the input torque of the wind generator. System frequency could fall as low as 59.5 hertz when the diesel is fully loaded and the wind generator is idling. This condition would occur when the wind velocity is varying around 8 miles per hour, and the wind turbine would be taken "off line" to prevent excessive reverse power flow. When the output of the wind generator is greater than the Town's demand the remainder of its output is dissipated in the load bank.

Numerous tests and refinements have been made to achieve a high level of performance. Modifications on the basic design have been directed in the following areas:

1. Yaw system drive torque and bedplate-to-tower coupling

The orginal hydraulic motors used to yaw the machine proved

to be insufficient in terms of torque capabilities. They were replaced with motor/transmission units. A slight decrease in the yaw rate occurred, but the torque was increased to a level sufficient to drive the machine under any condition. The bedplate to tower coupling was provided with a 72 inch disc brake with three hydraulic calipers. This brake maintains a very stiff coupling at this critical union.

2. Control system bandwidth

The original signal conditioning and output actuating equipment was found to be insufficient in response, to accurately control the frequency of the wind turbine in wind velocities above 25 miles per hour. The wind generator was always stable in operation when "locked" in synchronism with a stable source of approximately 4 times its nominal capacity. Used in "Infinite Bus" applications, interface should present no difficulty with the system as presently configured. Work is being done to increase the effective range of operation for remote applications such as Cuttyhunk. The faster control system should be operational by May, 1979.

## COST

We are continually working to increase the performance and lower the cost of this system, without sacrificing reliability. At present production costs, Figure 6 , are of prime interest. Our goal, as stated earlier is $1,000 per installed kW. At this time WTG Energy Systems is quoting a price of $226,000 FOB the plant, or approximately $1,130.00 per kW. We have calculated that with a production run of 5 units the per unit cost could be reduced by 30%. This would equal an FOB cost of $158,000 or $791.00 per kilowatt.

## FUTURE R & D REQUIREMENTS AND SUGGESTIONS

The areas in the design and operation of the MP1-200 system in particular, and, wind turbine generator systems in general requiring additional research and development are listed below.

1. Increased field testing of large wind turbines interfaced with small hydro electric installations should be given high priority. This application has the potential of allocating greater capacity credits for both systems.

2. Increased emphasis on field testing wind turbine/diesel packaged systems. Emphasis should be placed on the design of diesel engine combustion requirements operating with reduced loads and the retrofitting of existing units for similar operational parameters.

3. Field testing of multiunit wind generating systems interfaced

with conventional grid systems. Of particular interest are combination systems each with equal installed capacities.

## CONCLUSION

To date the system has met or exceeded the original design criteria. We feel that this system demonstrates that synchronous power can be produced directly from a wind driven generating system at a cost that is competitive, in many areas, with conventionally powered generating systems.

We are continuing to work on improvements in the control system, on production techniques and methods of installation to futher reduce the system's cost and increase its reliability.

## DISCUSSION

Q. Can you discuss the blade construction?

A. That will be covered in a later paper by Bob Barrows, the chief engineer of this project. I will let him answer that question.

Q. What is the rotor diameter and rated power?

A. The rotor diameter is 80 feet, and the rating is 200 kilowatts in a 26 to 28 mph wind.

Q. What is your assessment of the market potential, in dollars per year over the next five years, for intermediate size machines?

A. Since we had our press conference, we have written about ten proposals to utility companies all over the world--in Australia, Africa and some in the United States. There are about 500 small diesel utilities in the United States that are in high wind areas. That's the best I can tell you right now. We are in the process of doing a lot of work in this area. As a matter of fact, we are spending most of our money and time on this aspect of the business.

Q. How much energy is being discarded during the winter and summer months?

A. No energy is thrown away in the summer, as this is the island's peak demand period. At night during the winter, the demand for the island often drops to as low as 20 kilowatts while the wind turbine is operating at maximum output. During this period quite a bit of power is discarded.

The island's power plant is a municipal plat. Presently no heat, hot water and cooking requirements are part of the utility's demand. If more of the island's energy requirements were served by the utility, less would of course, be burned off. Ultimately, it will be up to the utility and the residents to decide how much of their total demand should be electrical and the economic value of the conversion.

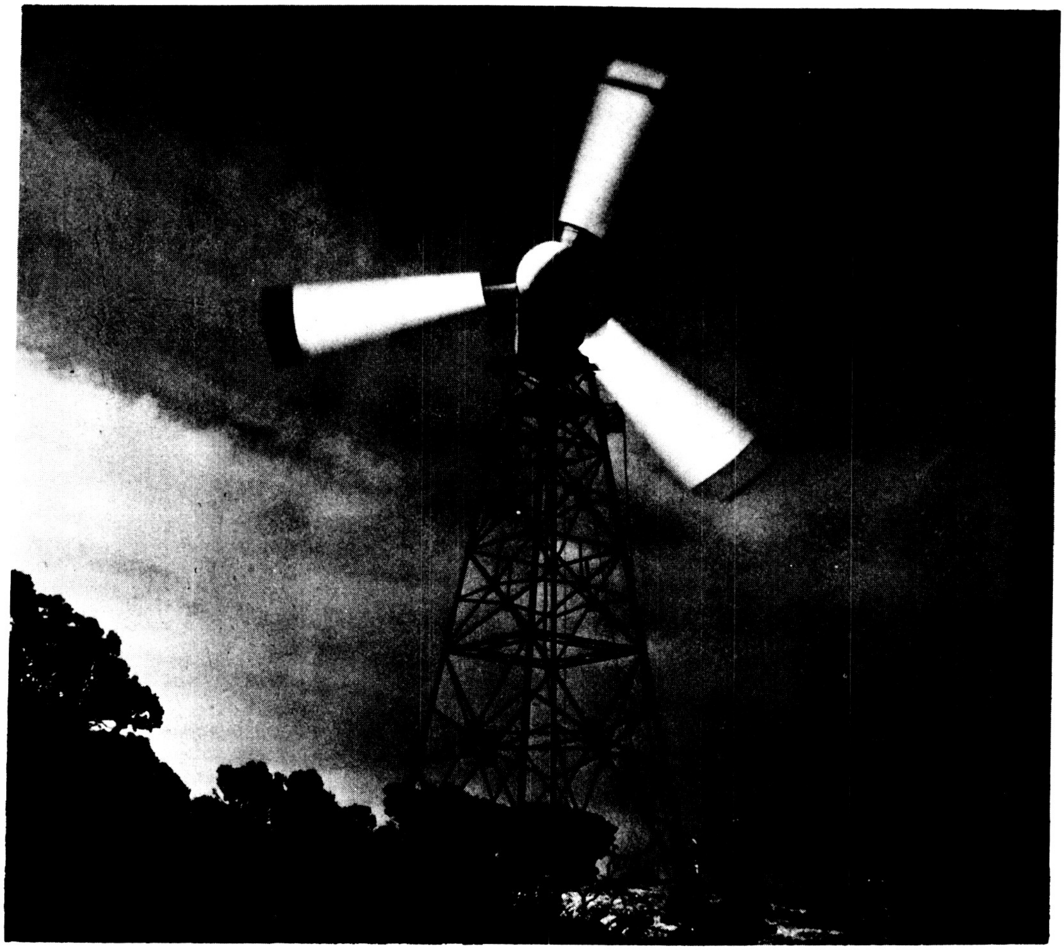

Figure 1. - MP1 - 200 wind turbine generator. (Photo courtesy of Eagle Signal Division, Gulf and Western Manufacturing Company.)

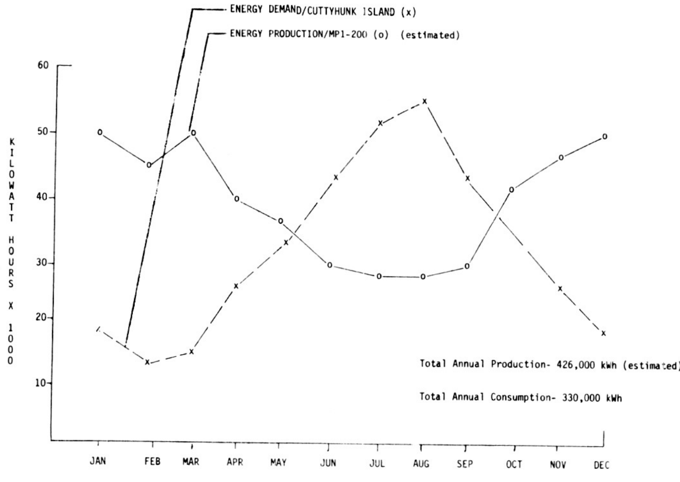


Figure 2. - Energy comparison.

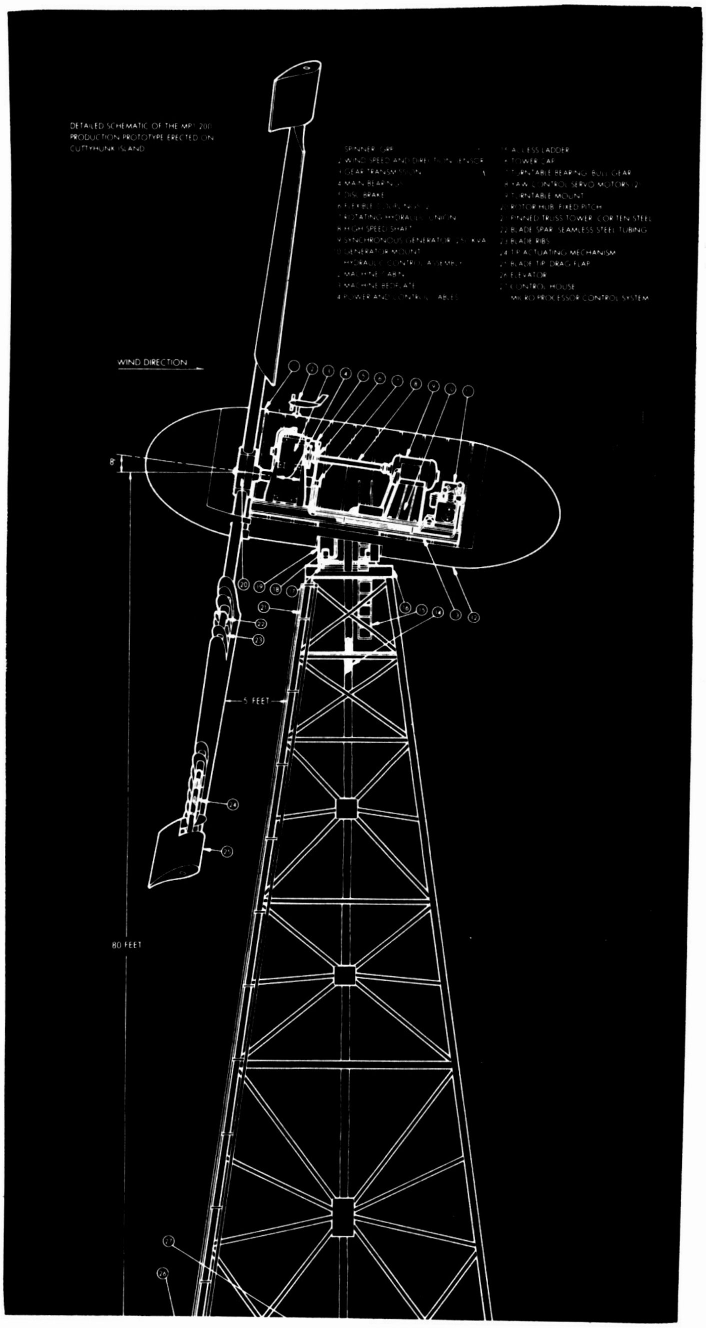


Figure 3. - Wind turbine generator components.

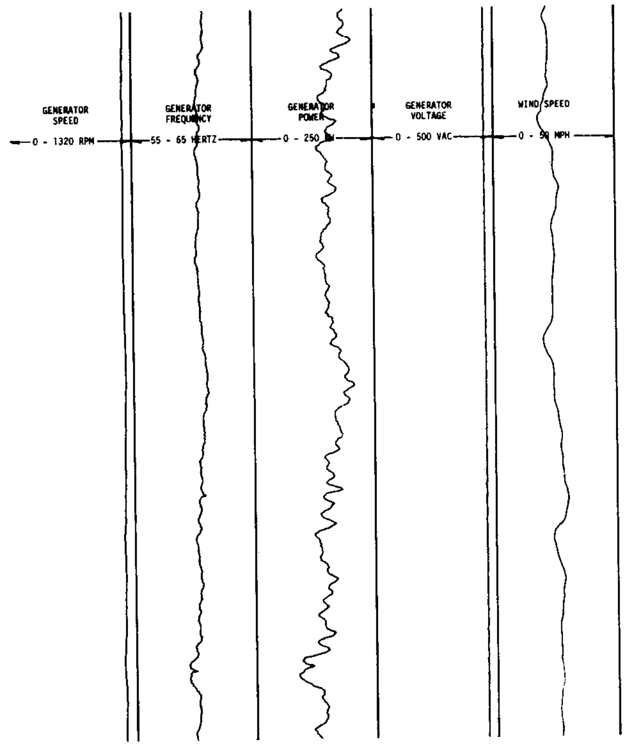


Figure 4. - Wind generator regulation.

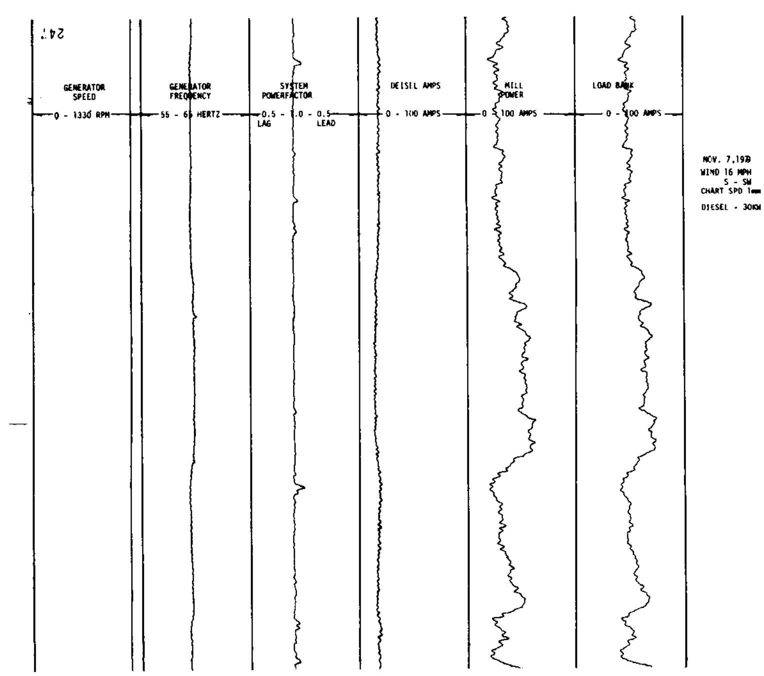


Figure 5. - Performance under synchronous operating conditions.

| COMPONENT | PER CENT OF TOTAL COST | COST |
|---|---|---|
| RIBS | 18.4% | $ 7,560.00 |
| SPARS | 12.3% | 5,040.00 |
| HUB | 18.4% | 7,560.00 |
| TIP FLAPS | 13.8% | 5,670.00 |
| BLADE SKIN | 5.4% | 2,250.00 |
| MISC. HARDWARE | 4.9% | 2,030.00 |
| LABOR | 26.8% | 10,810.00 |
| TOTAL | 100% | $ 40,920.00 |

Figure 6. - Cost breakdown MP-1 200 rotor system by major components (sale price for limited production).